

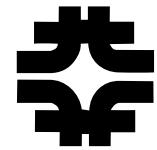
FNAL View of Neutrinos

Off-Axis Detector Workshop

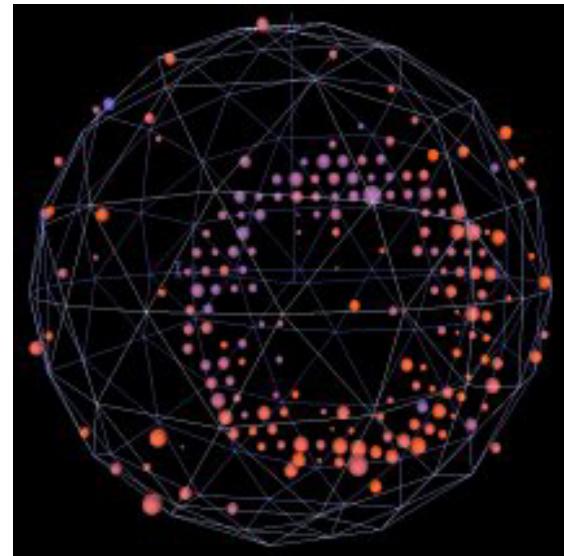
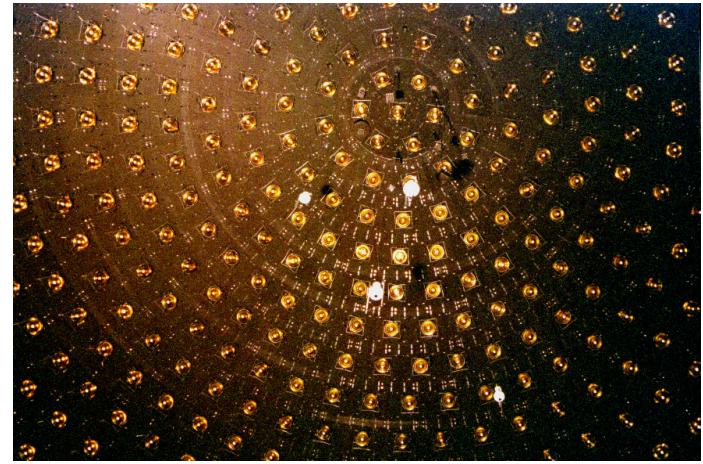
Hugh Montgomery

January 24, 2003

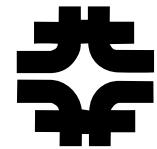
MiniBooNE has started



- First event September 2002
- Neutrino Beam operates 140 hrs per week
- Neutrinos per proton as expected
- Events match Monte Carlo
- Currently $> 2 \cdot 10^{18}$ pot per week, rising steadily
- Increases towards design in careful stages.
 - MP02 Power Supply
 - MP02 Magnet
 - Collimator Shielding
 - ...
- The Booster MUST survive



MiniBooNE Operations



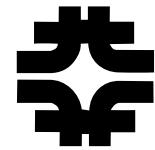
Goals

Week ending	prot. per pulse	pulse per sec.	prot. per hour	Beam eff.	prot. per day	prot. per week	prot. Improve. /yr (280 da)
	10^{12}	Hz	10^{16}	%	10^{18}	10^{19}	10^{20}
Goal	5	5	9	83%	1.79	1.25	5.00
11-Nov	4	0.89	1.28	73%	0.22	0.16	0.63
25-Nov	4	1	1.44	80%	0.28	0.19	0.77
2-Dec	4.1	1.12	1.67	88%	0.35	0.24	0.98
9-Dec	4.1	1.4	2.07	80%	0.40	0.28	1.11

Dec 9, 2002

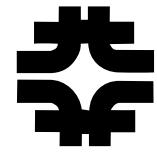
All Experimenter's Meeting
Ray Stefanski

Current Operations



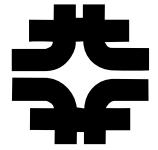
- Booster
 - Protons per cycle
 - 4.5×10^{12} on pbar production cycles
 - 4.1×10^{12} on MiniBooNE cycles
 - Losses are non-linear from about 4×10^{12} up
 - Repetition Rate
 - 0.4 Hz on pbar production
 - 1.8 Hz overall
- Main Injector
 - Cycle time
 - 2.2 secs is typical
 - Rise/fall time corresponds to minimum 1.46 sec cycle.
 - Primary limitation comes from antiproton cooling

Issues being Addressed



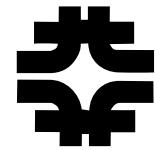
- Booster
 - Repetition rate
 - New MP02 Magnet installed in Jan 2003
 - Loss Mitigation
 - Collimator Shielding to be installed early 2003
 - Ramp Correctors
 - Better Understanding
 - Active “Space Charge” Study Group
 - Defined program of measurements
 - Measurements underway
 - Simulations
 - Experiments aware and involved

Issues being Addressed



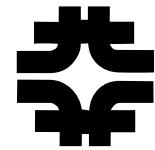
- Main Injector
 - Multibatch Operation
 - RF gymnastics, have worked in the past and were recently reestablished
 - Dampers (needed because of intensity) are under development

Management

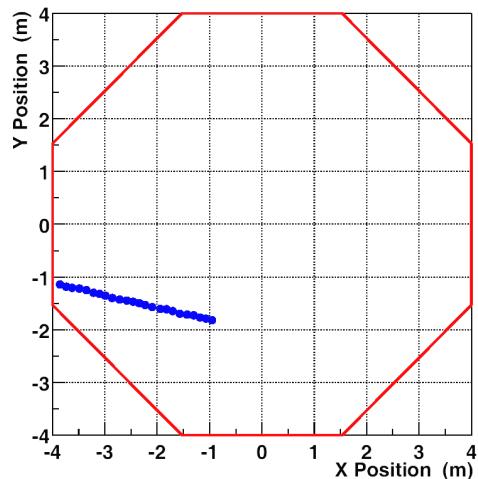


- **Step 1: Ad Hoc Committee**
 - Define the work required to assure the Base Goal for NuMI of:
 - 2.5E13
 - 1.9 sec cycle
 - Look at realistic expectations for a stretch goal as a function of time for the Booster and Main Injector.
 - Chair is in place, Finley,
 - Charge in Draft form
 - Establish committee in next week
- **Step 2: Organization**
 - Plan
 - Execution
 - Participation from current NUMI Physicists
 - Participation from MINOS Physicists broadly

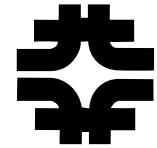
Status of the NuMI/MINOS Project



- Tunnels and Halls construction complete 11/22/02
- Surface Buildings and Outfitting construction started 11/1/02
- >387/484 planes of MINOS far detector installed and operating
- Cosmic ray studies underway
- Serious risk of being ready for beam in less than than 2 years

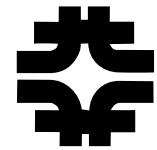


Fermilab PAC & MINOS



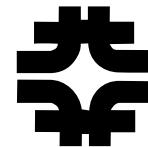
-
- Liked the Veto Shielding initiative, encouraged pursuit (June)
 - Was very pleased that MINOS had followed their advice on the Veto Shield (November) and have a fraction operational and prospects for the balance.
 - Was very impressed by the progress made by NuMI & MINOS and the way the Far Detector components are brought into operations immediately.
 - The PAC would like to see a study of physics sensitivity to numbers of protons on target. For example, what is needed:
 - To exclude neutrino decay at 95% cl
 - To see 3σ preference of oscillation hypothesis versus decay hypothesis
 - To see 5σ dip in the oscillation curve

Fermilab PAC November 2002



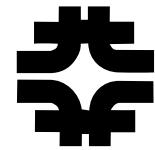
- A number of Neutrino initiatives
 - NuMI Off-Axis Long Baseline Detector
 - Several Short Baseline letters
- While reaffirming the interest, expressed during the summer, in an evolving neutrino program, the PAC emphasized that, if given a choice of where to put resources in the near term, then we should choose to **ensure that the accelerator complex can deliver the protons**

Fermilab PAC November 2002



- | | |
|-------------|---|
| 2:00 - 2:20 | Letter of Intent to Build an Off-Axis Detector to Study
$\nu_\mu \rightarrow \nu_e$ Oscillations with the NuMI Neutrino Beam (A. Para) |
| 2:30 - 2:50 | Detector R&D for Future Experiments with the NuMI
Beamline (D. Harris) |
| 3:00 - 3:20 | Expression of Interest in Construction of an Off-Axis Near
Detector to Measure Neutrino Cross Sections on Nuclear
Targets in the Few GeV Region with the NuMI Beam (K. McFarland) |
| 3:30 - 3:45 | Break |
| 3:45 - 4:05 | Expression of Interest to Perform a High-Statistics Neutrino
Scattering Experiment Using a Fine-Grained Detector in the
NuMI Beam (J. Morfin) |
| 4:15 - 4:35 | Expression of Interest: Physics with a Near Detector on the
Booster Neutrino Beamline (B. Fleming/R. Tayloe) |

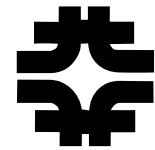
PAC June 2002: P-929



P-929 Letter of Intent to Build an Off-axis Detector to Study $\nu_\mu \rightarrow \nu_e$ Oscillations with the NuMI Neutrino Beam (Para)

The Committee thanks the proponents for their Letter of Intent for an experiment in the off-axis NuMI beam and appreciates this effort to flesh out an optimum experiment to measure θ_{13} . Such a measurement is the crucial next step towards the long-range goal of observing CP violation in neutrino oscillations. The Committee encourages continued discussion within the neutrino community on how best to achieve these ambitious goals.

More detailed discussion of the off-axis experiment, which was also discussed in the proton-driver report, is given below.

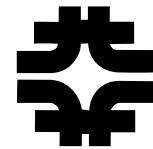


Issues for Off-Axis Neutrino Oscillation Experiments

As has already been discussed, the next important problem in the study of neutrino mixing is to measure θ_{13} . It is especially interesting to search for θ_{13} in the parameter range within about a factor of 10 below the Chooz limit, because this is the region in which it may be feasible to detect CP violation in neutrino mixing with conventional ν_μ beams without having to build a muon storage ring.

However, the Committee notes that the measurement of θ_{13} in an off-axis experiment using the currently planned NuMI beam with 2.5×10^{20} protons/year is very challenging. For example, a 20 kton experiment would only observe 1 signal event per year if $\sin^2 2\theta_{13} = 0.01$, and a comparable number of background events.

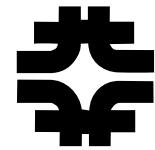
Fermilab PAC, June 2002: Neutrino Initiatives



At the Aspen meeting, the PAC considered two submissions addressing initiatives which go beyond the neutrino program consisting of the NuMI/MINOS and MiniBooNE experiments. The PAC response to a potential extension of the neutrino program was positive. Therefore, we will encourage a series of workshops and discussions, designed to help convergence on strong proposals within the next few years. These should involve as broad a community as possible so that we can accurately gauge the interest and chart our course. Understanding the demands on the accelerator complex and the need for possible modest improvements is also a goal. Potentially, an extension of the neutrino program could be a strong addition to the Fermilab program in the medium term. We hope to get started on this early in 2003.

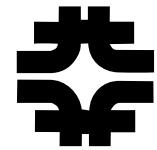
Michael Witherell

Questions (mine)



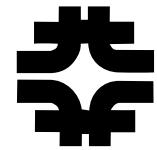
- Trying to understand for myself the issues
 - Letters of intent for Fermilab
 - Internal NuMI documents
 - Proton Driver studies
 - BNL study document
- How well can straight-ahead NuMI/MINOS do $\nu_\mu \rightarrow \nu_e$?
- Are there simple modifications which make NuMI/MINOS do much better?
- Are there optimum energies and distances?
- How do those optima depend on the particular parameter of interest, θ_{13} , matter effects, δ ?
- Given, what we know, is there a series of obvious scales which we should put to our ambitions?
- (Is there something to learn from how we handled kaon exploration??)

Lecture/Discussion Series



- **Organizers: Leslie Camilleri, Stephen Parke**
- **Modelled after Tunnel Vision, Circle Line, Line Drive, Starry Messages series**
- **5-6 Seminars/Jamborees between February and end of May**
- **Thursday Afternoons**
- **Tentative Program in discussion**
- **Intent is to inform on the “Off-axis” discussion**

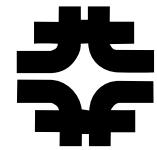
Proposal??



- **Need:**
 - Well defined physics goal
 - Well defined detector concept
 - Understanding of the flexibility in each
 - Substantial Proposal
 - Will there be an R&D phase?
 - How substantial?
 - Does there need to be an R&D proposal?
- **Lab is committed to BTeV and CKM**
 - Note the ongoing discussions (later)
- **Are there sources beyond DOE/FNAL?**
- **Is NSF interested?**

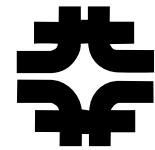
Issue is primarily one of pace

PPPPP - Exists



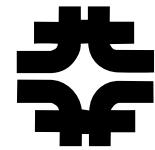
- Structure is Sub-panel
 - (General) Charge received/agreed by HEPAP
- Chairman: Abe Seiden
 - Members known
- Meetings:
 - January – charge, projects?, survey of the land
 - March – hear from proponents, labs?
 - Early Summer, write report, conclude
- Projects.
 - Run IIB (CD3B), BTeV, CKM

Office of Science: Facilities



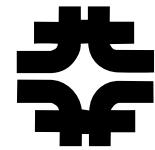
- Letters from Ray Orbach to Advisory Committee Chairs
 - BESAC, NUSAC, HEPAP
- Requests advice on submitted lists of Facilities
 - HEP submitted 13 “facilities”
 - Linear Collider (multi-billion) to CKM (tens of millions)
 - Comment on:
 - how central/important to the science
 - readiness
 - By March!
- Gilman using P5 plus some of HEPAP members
- Letter from Gilman to “proponents”
 - Ten page narrative by February 7

HEP “Facilities”



- PROJECT TITLE: Linear Collider
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: SuperNova Acceleration Probe (SNAP)
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: Off-Axis Neutrino Detector
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: Super Neutrino Beam (Proton Driver)
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: Proton Decay Detector
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: Double-Beta Decay Detector (Liquid Xenon)
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: Muon Storage Ring / Neutrino Factory
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B

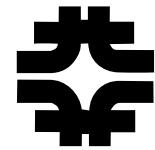
HEP “Facilities” Continued



- PROJECT TITLE: Charged Kaons at the Main Injector (CKM)
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE : LHC Detector Upgrade
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: BTeV
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: LHC Accelerator Upgrade I (10X Intensity)
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE: LHC Accelerator Upgrade II (Energy Doubler)
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B
- PROJECT TITLE : Super B-Factory
 - First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B

PROJECT TITLE: Off-Axis Neutrino Detector

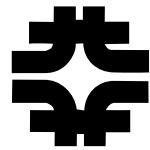
First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B



- **SCIENTIFIC IMPORTANCE:**
- A large “off-axis” neutrino detector would expand upon and complement the accelerator-based neutrino physics program that will soon begin with NuMI/MINOS, and further capitalize on our investment in the NuMI facility.
- The discovery of neutrino oscillations by the Super-Kamiokande experiment in 1998 has firmly established that neutrinos are massive particles. This is a deviation from the Standard Model of Particle Physics in which neutrinos are assumed to be massless entities.
- The next round of experiments will need to focus on the elucidation of the phenomena of neutrino masses and oscillations.
- A first step toward exploring the physics will be understanding the rate at which the three known neutrino species “mix,” or change identities. Current measurements from other experiments indicate that a crucial parameter characterizing neutrino physics will be the rate at which electron-neutrinos mix into other species.
- The NuMI neutrino beam, under construction at Fermilab, will aim at the MINOS detector located in the Soudan mine in northern Minnesota, about 750 kilometers away. MINOS is designed to precisely measure the mixing of muon-neutrinos into other species, following up on the Super-Kamiokande results.

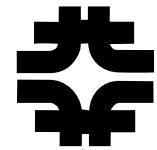
PROJECT TITLE: Off-Axis Neutrino Detector

First Estimate : \$50M -\$99M \$100M-499M \$500M-\$1B >\$1B



- **SCIENTIFIC IMPORTANCE:** Continued
- A large surface detector (~20 kilotons) off-axis of the NuMI beam by a few degrees with respect to the beam axis would detect electron neutrinos with a well defined energy, yielding a measurement of electron-neutrino mixing with values as small as 0.0025.
- Even a small non-zero value of this parameter would signal the possibility of CP violation in the neutrino sector. CP violation is needed to explain the fact that our universe is mostly made of matter and not antimatter.
- It is experimentally known that charge-parity (CP) symmetry is not conserved, referred to as CP violation, in the weak interaction of quarks. It has never been observed in leptons such as neutrinos, though it is theoretically possible.
- If CP violation is observed in leptons, it would have a significant impact on our understanding of the origin of mass and the evolution of the universe. It is now understood that CP violation in quarks is insufficient to account for the observed dominance of matter in our universe, so there must be other sources of CP violation at work in the early universe. CP violation in neutrinos may be the answer.

Summary



- The Fermilab PAC considers that the future possibilities for neutrino physics at Fermilab are interesting
- Fermilab, the Laboratory, would like to see future exploitation of the NuMI Beam.
- The key to everything is indeed the ability of the accelerator complex to deliver protons
- Depending on how things evolve with a Linear Collider, Fermilab will seriously consider an intense proton source for neutrino and other physics as a potential anchor for the physics of the Laboratory.